Written: RC3, Tab 1
Oral: RC3, Tab 3

Proposal 261
Recommended harvest strategy for Bering Sea Tanner crab

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[3] The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author(s) and do not necessarily reflect those of NOAA or the Department of Commerce.

Highlights

1. Positive collaboration
   - ADF&G developed new harvest strategy options
   - Industry stakeholders provided feedback throughout
     - High value fishery, variable TAC, closures, complex harvest strategy
   - NOAA and UW conducted the analysis
2. Introduction to Management Strategy Evaluation (MSE) application
3. 15 harvest strategies evaluated
   - Narrowed down to 1 strategy with 3 sub-options for BOF consideration
     - Alignment across collaborators, with some differences in final preference

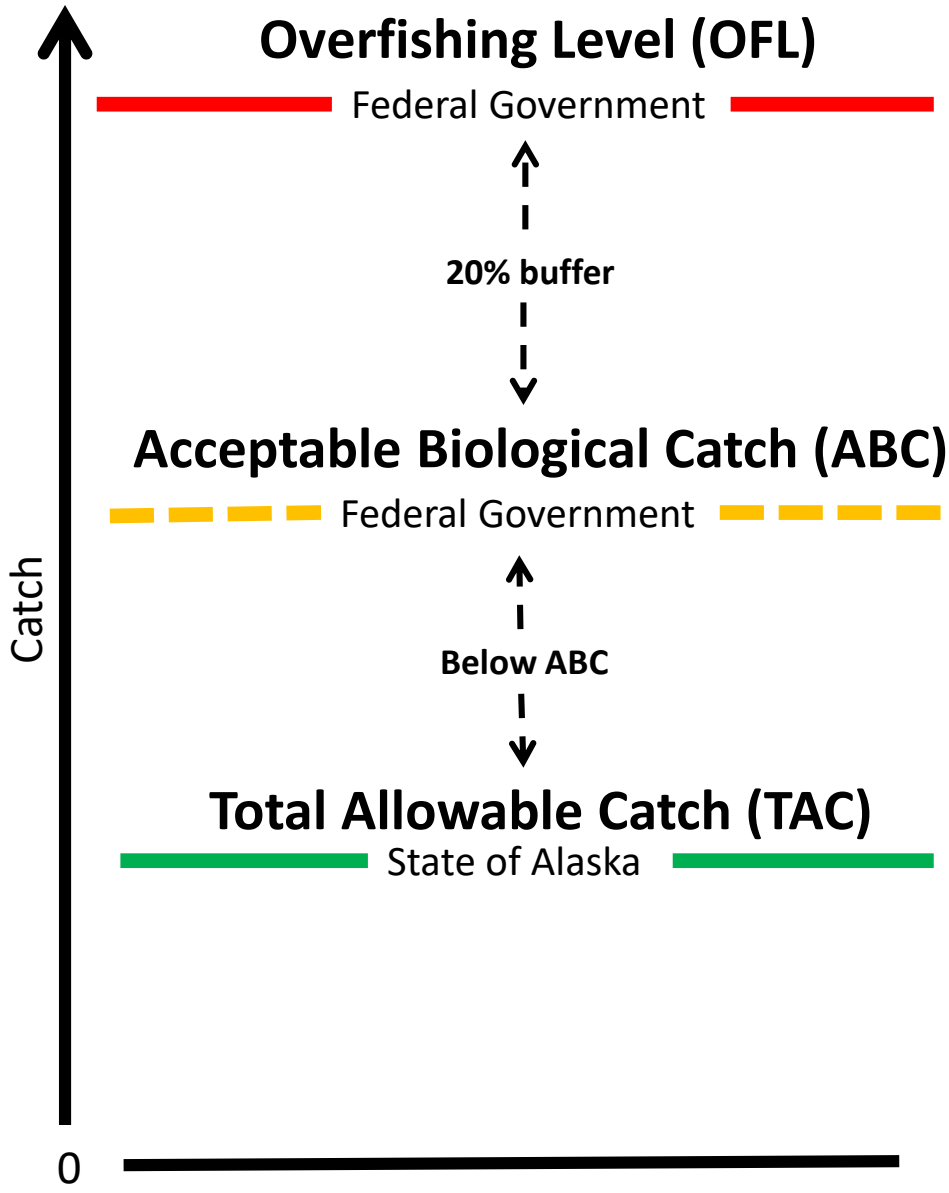
State/Federal cooperative management regime

Federal process:

- NPFMC FMP: 10 BSAI crab stocks
- Stock assessment
  - OFL (overfishing level): threshold for overfishing
  - ABC (acceptable biological catch): below OFL to account for "*the scientific uncertainty in the estimate of OFL and any other specified scientific uncertainty*"

State process: harvest levels and other management actions

- BOF Policy on King and Tanner Crab Resource Management, FMP, MSA national standards
- FMP Amendment 38: optimum yield ranges from 0 – <OFL
  - Sum of all sources of fishing mortality <ABC



OFL: Level of fishing mortality that jeopardizes the capacity of a stock to produce the maximum sustained yield on a continuing basis.

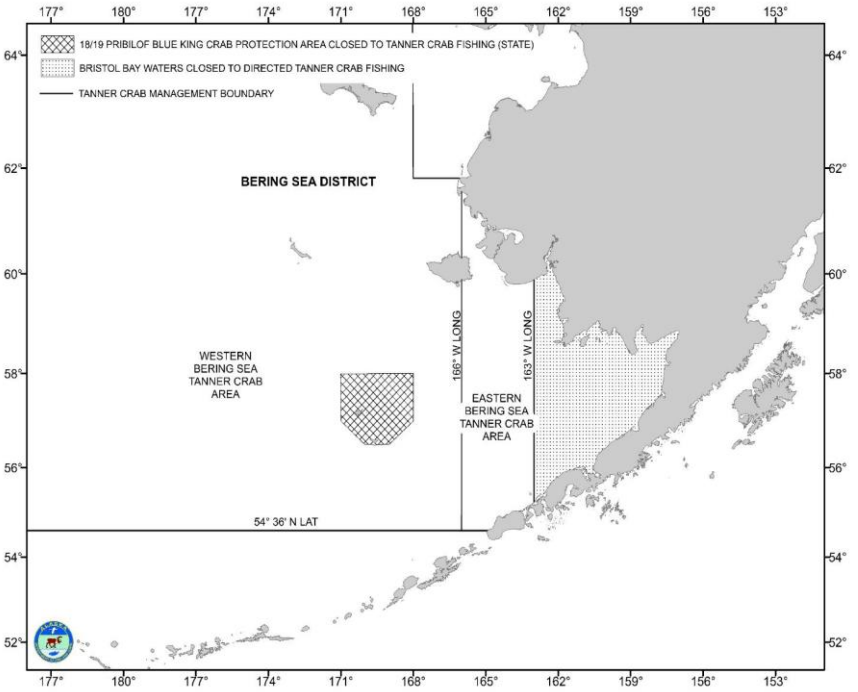
ABC: Level of annual catch that accounts for scientific uncertainty and is set to prevent the OFL from being exceeded.

In practice ABC limits mortality of **ALL** male and female crabs regardless of size, from all sources of fishery mortality (i.e. retained catch, bycatch in directed and non-directed crab fisheries, and groundfish fisheries).

TAC: Annual catch target for the directed fishery, set to prevent exceeding the ABC for that stock. **Limits legal sized males**, but must consider all sources of mortality to ensure the ABC is not exceeded. Considers model uncertainty and other factors.

Current fishery management

- Managed east/west of 166° W longitude
- Size:
  - *Legal:* **4.8 inches** east **4.4 inches** west
  - *Industry-preferred:* **5.0 inches** both areas
- Sex: male only
- Season: October 15 to March 31
- Gear: pots
- Fleet: ~35 vessels
- Total allowable catch (TAC) scaled to population abundance



Rationalized fishery:

- TAC apportioned to harvester quota shares (IFQ), processor quota shares, community development quota
- Industry cooperatives: improves harvesting efficiency

Need for harvest strategy revision

- Evolved in parallel with advancements in understanding of Tanner biology and assessment modeling approaches

- Most complicated of BSAI crab stocks
  - Mature female threshold triggers fishery closures or substantial TAC reductions (e.g., 2016/17 season closure)
  - Uncertainty surrounding application of female control rule

- 2017 BSFRF Tanner crab workshop
  - "*Workshop partners recommend an approach to revise the bairdi harvest strategy that improves the economic outlook to the industry and acknowledges the importance of the bairdi reproductive capacity to conserve the stock*"

Analysis objectives

Recognize policy mandates and conservation objectives

- Magnuson-Stevens Act national standards
- NPFMC FMP overfishing criteria (OFL/ABC)
- BOF Policy on King and Tanner crab Resource Management

Incorporate industry preferences

- Ad-hoc Bairdi Committee (harvesters, processor, communities) stated clear objectives:
  - Robust harvesting of exploitable males, when warranted (i.e., newshell)
  - Increase stability: reduce likelihood of season closures
- Iterative and transparent process:
  - Include feedback on policy scenario options
  - ADF&G presented preliminary results to industry

Management Strategy Evaluation (MSE)

Project population forward in time to compare different harvest strategy scenarios relative to fishery objectives

What the analysis is:

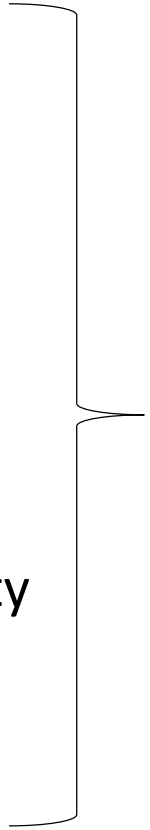
- A tool used to estimate relative differences in population sustainability and productivity

What the analysis is not:

- A crystal ball that will tells us exactly what will happen over the next 100 years

MSE methodology

- Projected population forward 100 years
  - 100 random replicates
- Estimated quantities:
  - TAC
  - Overfishing level (OFL)
  - Acceptable biological catch (ABC)
  - B0
  - Bmsy
  - Mature male biomass (MMB)
  - Mature female biomass (MFB)
  - Exploitable legal male biomass (ELMB)
  - ELMB_State: applies 40% oldshell selectivity
  - Annual recruitment
  - Male and female catch biomass
  - Male and female discard biomass



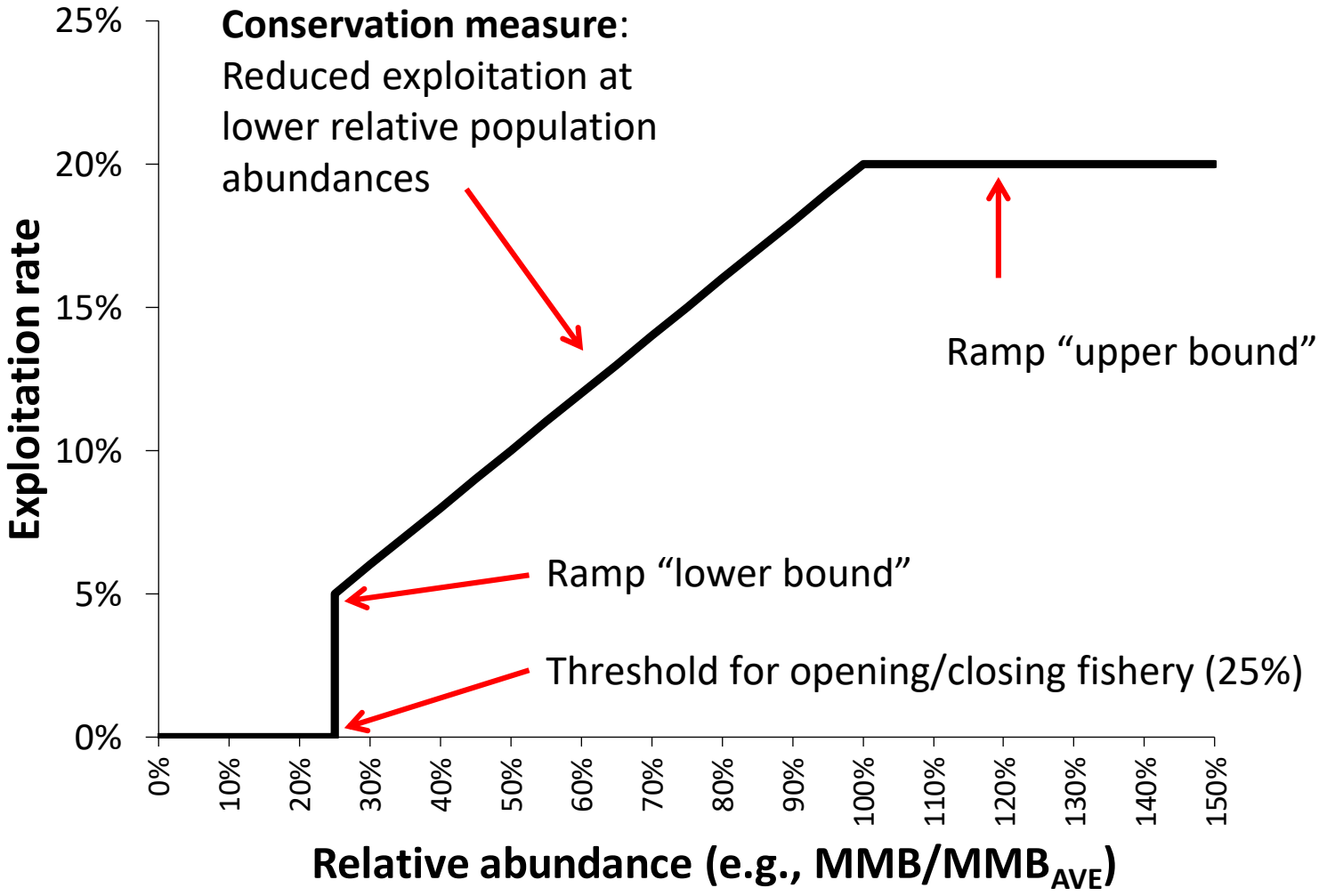
Then calculate probabilities of: exceeding conservation thresholds, meeting economic goals, etc.

15 Harvest strategies

Policy	Description	Fixed vs ramp	Ramp lower	Ramp upper	Max TAC
HCR1	Female ramp	Ramp	5%	20%	50% ELM
HCR2_R1	Male only 10%	Ramp	5%	10%	50% ELM
HCR2_R2	Male only 15%	Ramp	5%	15%	50% ELM
HCR2_R3	Male only 20%	Ramp	5%	20%	50% ELM
HCR2_R4	Male only 22.5%	Ramp	5%	22.5%	50% ELM
HCR3	TAC = $ABC_{5\text{-inch}♂}$	Ramp (F_{MSY})	NA	NA	NA
HCR4_1	Female dimmer 20%	Ramp	5%	20%	50% ELM
HCR4_2	Female dimmer 20%	Ramp	10%	20%	50% ELM
HCR4_3	Female dimmer 22.5%	Ramp	10%	22.5%	50% ELM
HCR4_4	Female dimmer 22.5%	Ramp	10%	22.5%	30% ELM
HCR5	Female blocks	Ramp	5%	20.0%	50% ELM
HCR6_30	ELM 30%	Fixed	NA	NA	30% ELM
HCR6_40	ELM 40%	Fixed	NA	NA	40% ELM
HCR6_50	ELM 50%	Fixed	NA	NA	50% ELM
HCR7	Status Quo	Ramp (F_{MSY})	NA	NA	NA

*iterations of the same harvest strategy concept

Sloping control rule

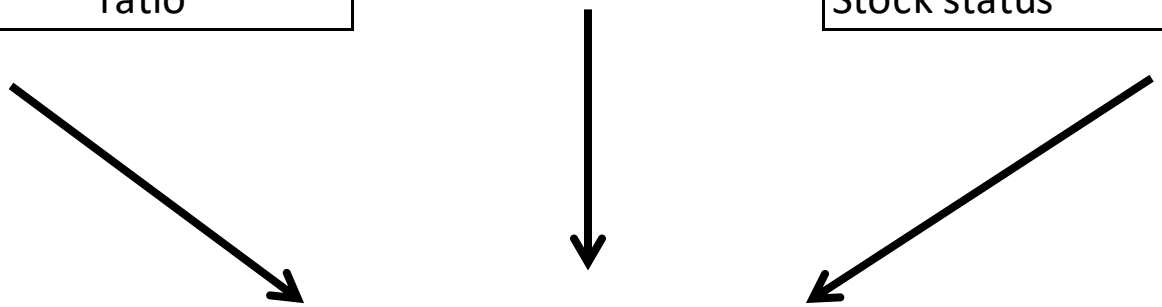


Evaluating harvest strategies

Conservation	
Metric	Unit
Overfished	Probability
Overfishing (OFL)	Probability
Overfishing (ABC)	Probability
MMB	Mill lb
MMB/MMB_{AVE}	ratio

Catch	
Metric	Unit
TAC	Mill lb

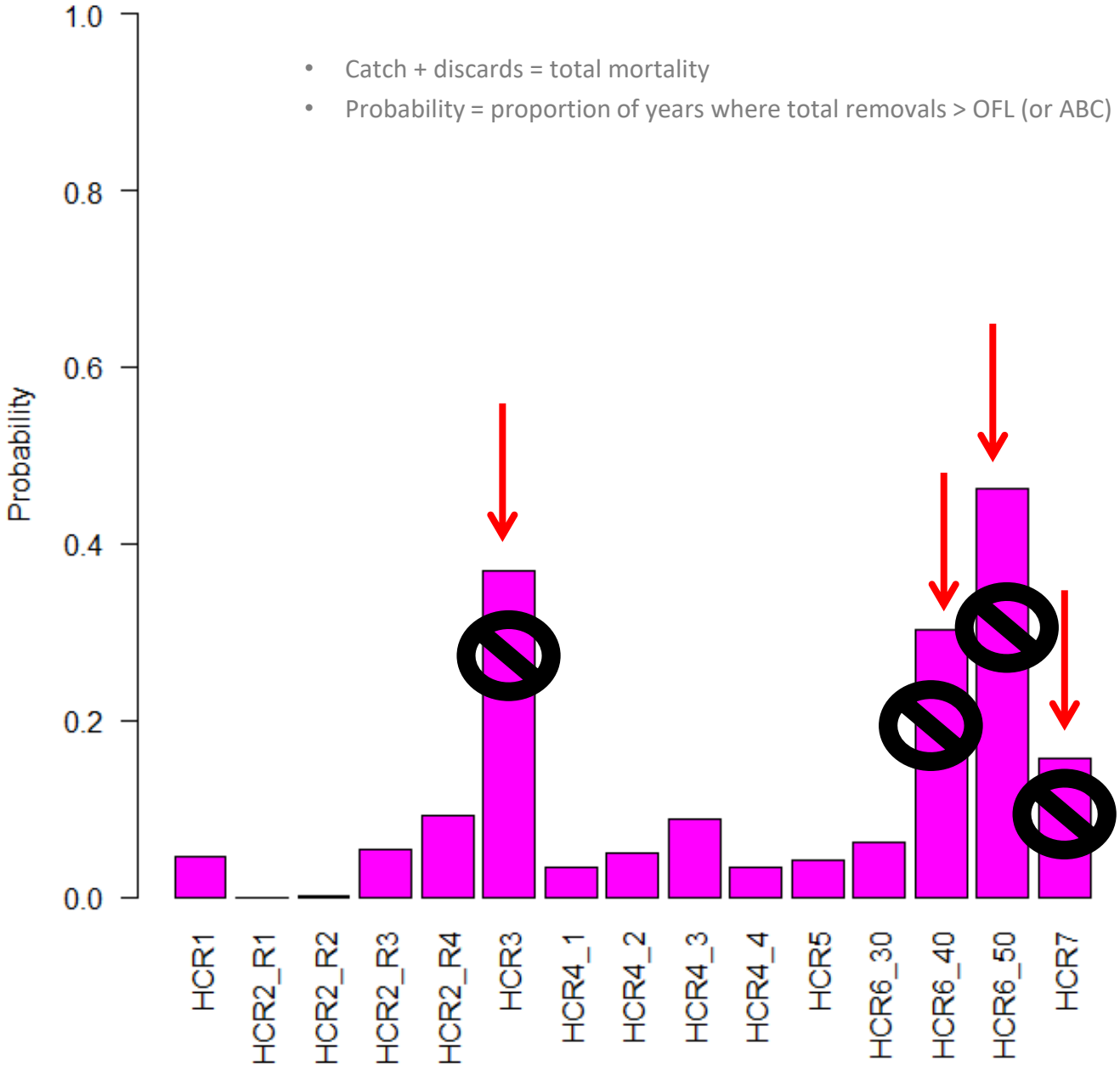
Catch Stability	
Metric	Unit
Fishery closures	Probability
Annual TAC var	Proportion
Relative TAC (1)	Probability
Relative TAC (2)	Probability
Stock status	Probability

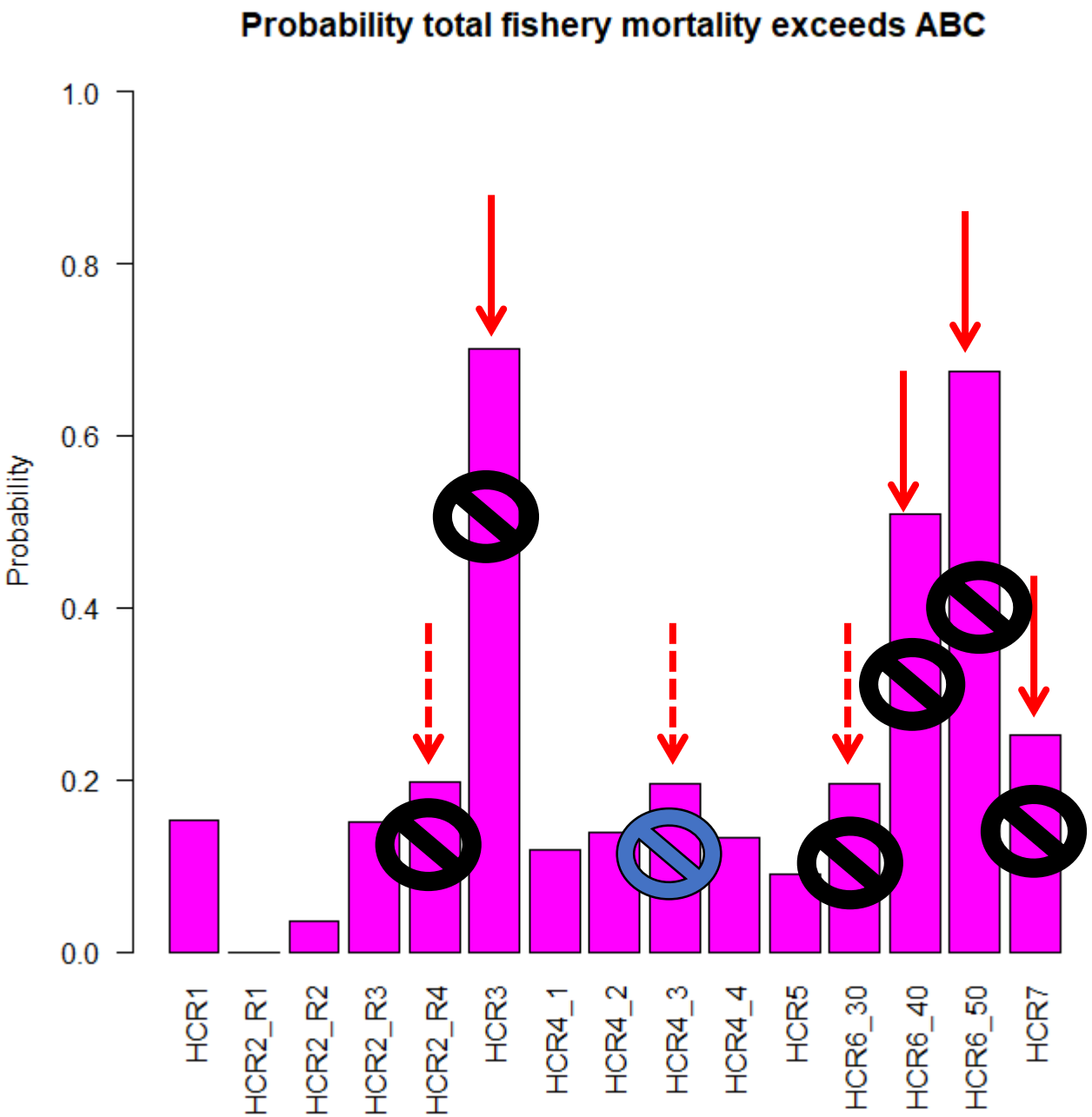


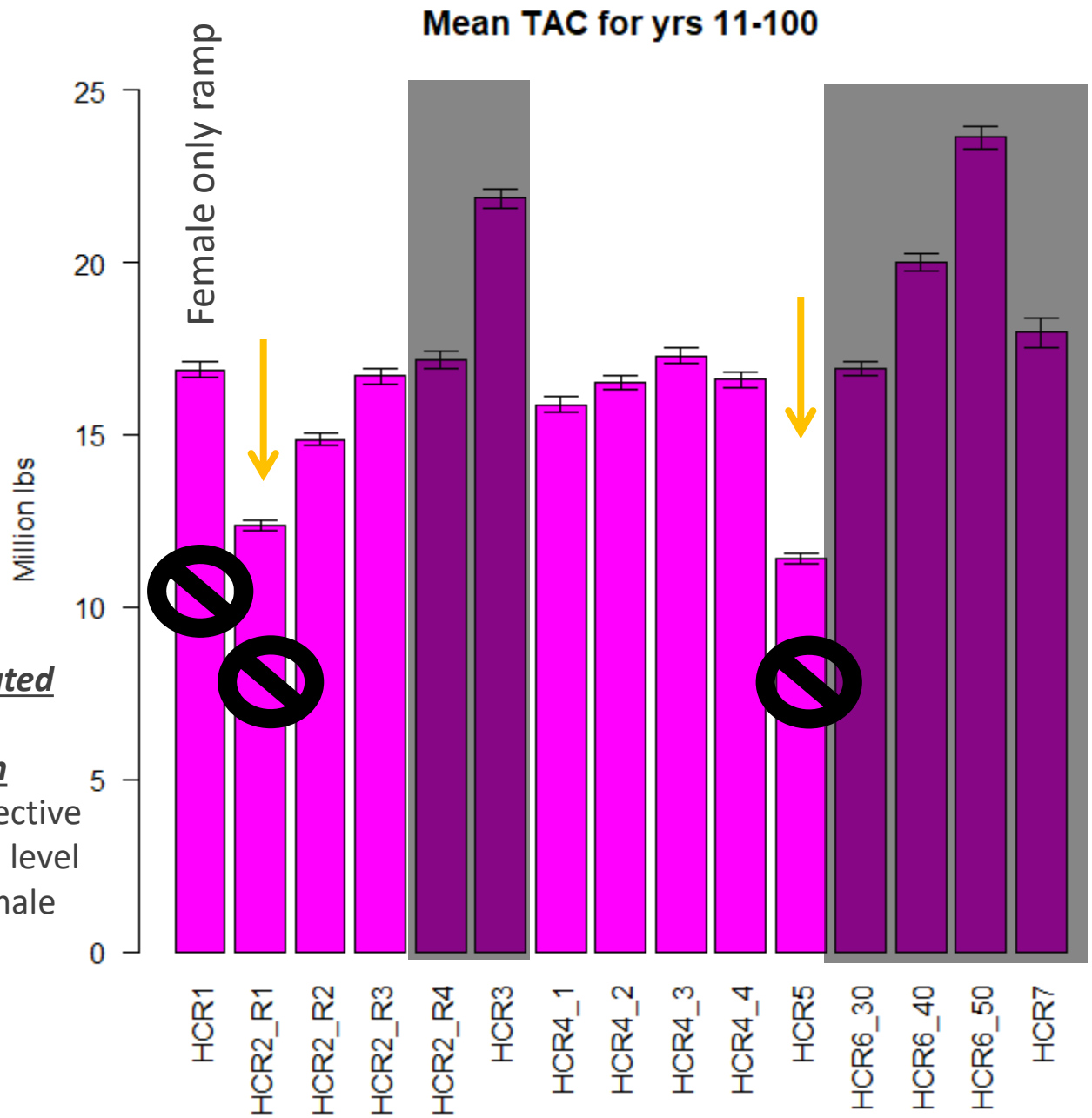
Single harvest strategy

Probability total fishery mortality exceeds OFL

- Catch + discards = total mortality
- Probability = proportion of years where total removals > OFL (or ABC)

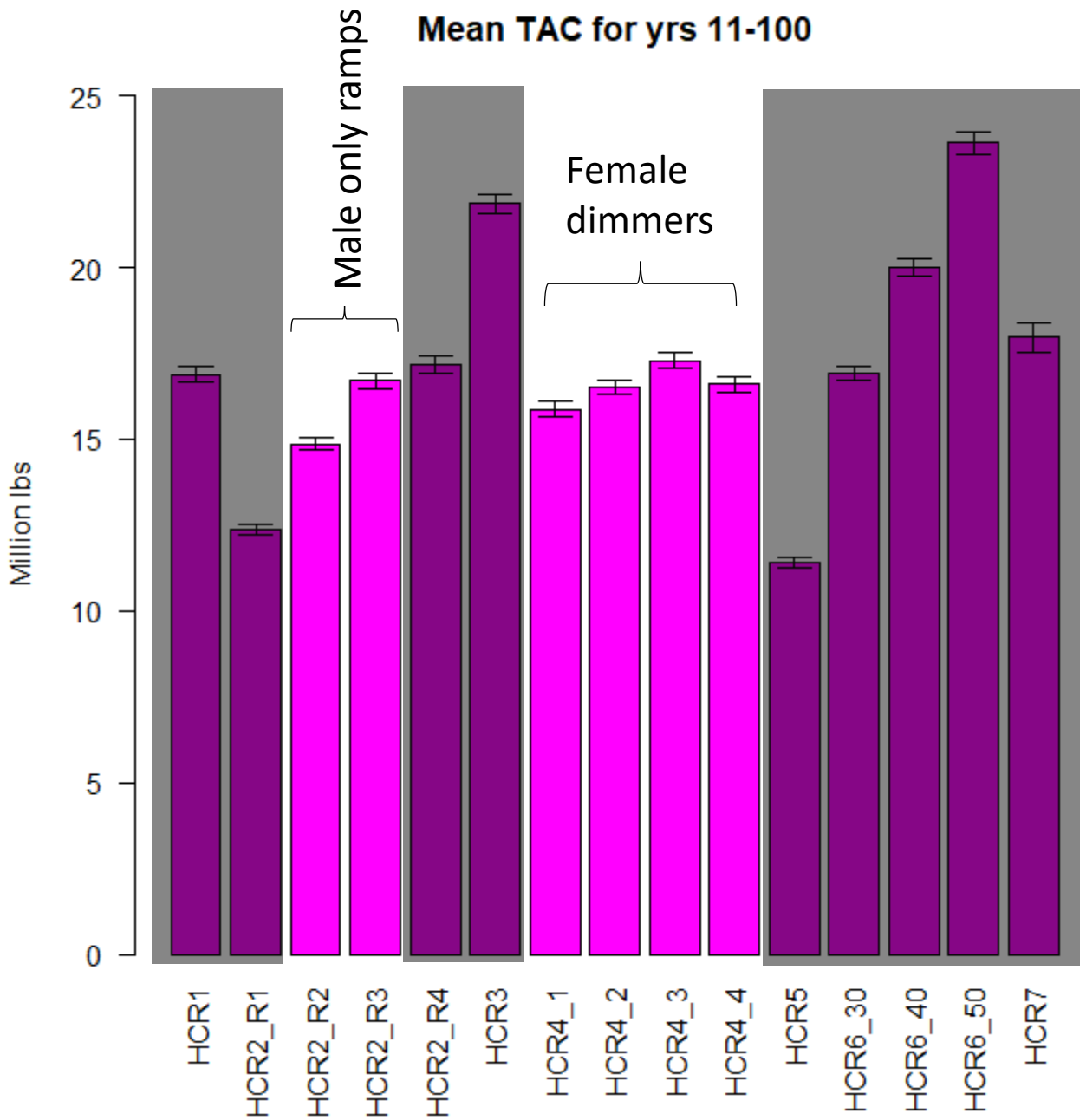



Probability total fishery mortality exceeds ABC
Probability
1.0
0.8
0.6
0.4
0.2
0.0
HCR1
HCR2_R1
HCR2_R2
HCR2_R3
HCR2_R4
HCR3
HCR4_1
HCR4_2
HCR4_3
HCR4_4
HCR5
HCR6_30
HCR6_40
HCR6_50
HCR7



HCR1 eliminated from consideration based on objective to reduce the level of explicit female control

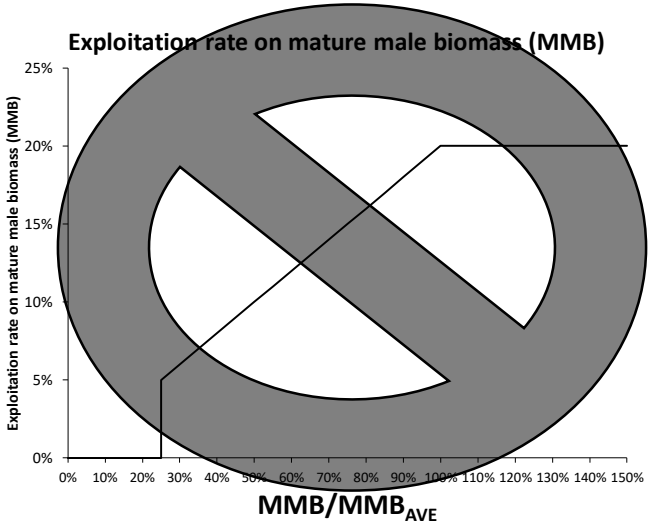
Orange Arrows: May not optimize yield


Mean TAC for yrs 11-100
Male only ramps
Female dimmers
Million lbs
25
20
15
10
5
0
HCR1
HCR2_R1
HCR2_R2
HCR2_R3
HCR2_R4
HCR3
HCR4_1
HCR4_2
HCR4_3
HCR4_4
HCR5
HCR6_30
HCR6_40
HCR6_50
HCR7

Final 2 harvest strategy concepts

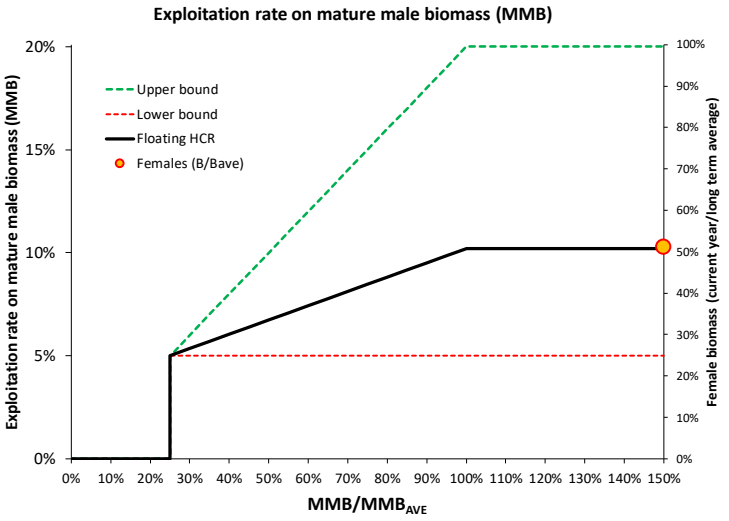
Male only ramp

- Ignores females
- Position on ramp dictated by relative MMB
- TACs based solely on MMB



Female dimmer

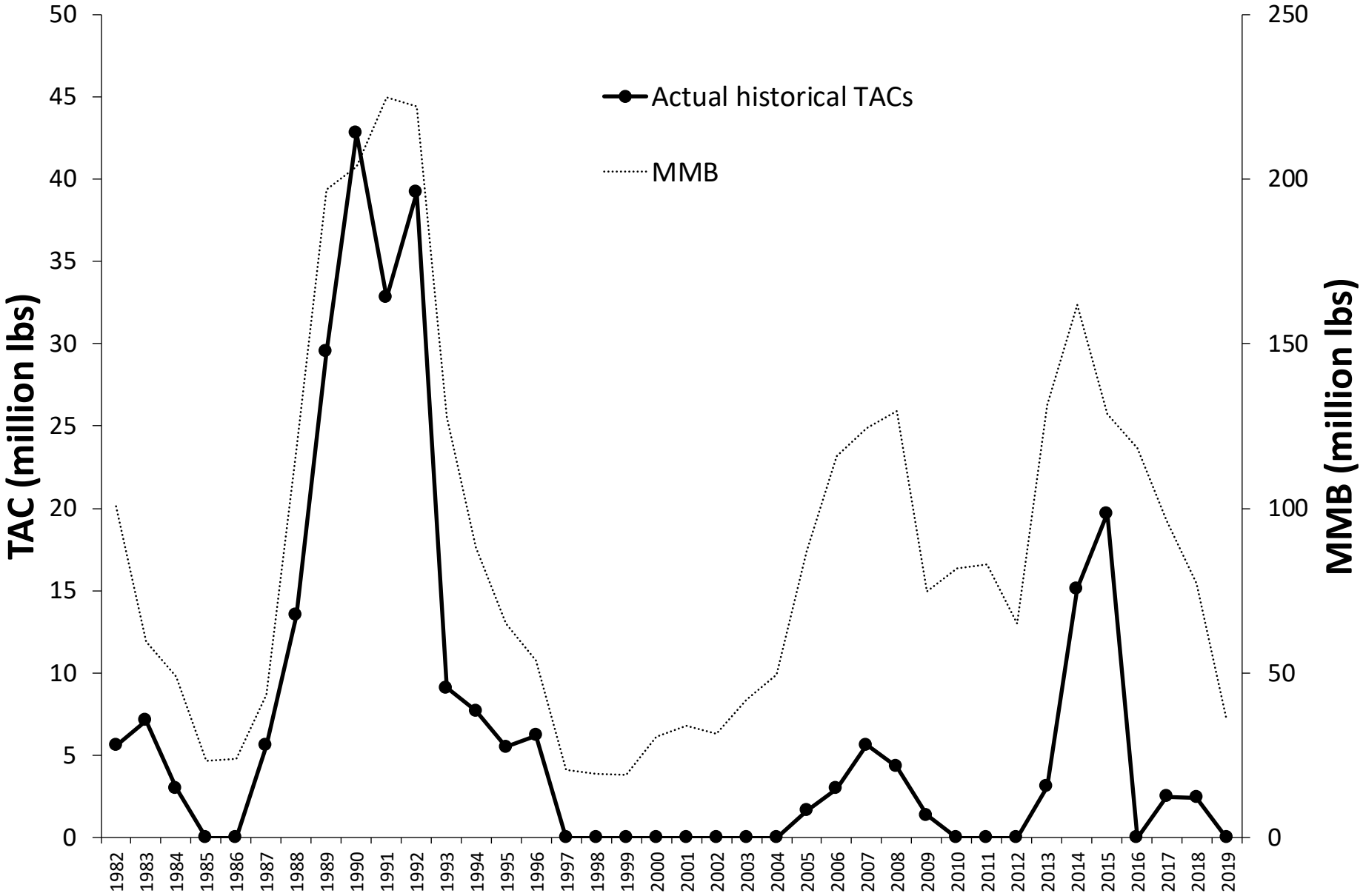
- Ramp maximum defined by relative MFB: the “dimmer switch”
- Position on ramp dictated by relative MMB



In practice, what does the female dimmer do?

- Consistent with 2017 Tanner workshop objectives
  - Improves the “economic outlook to the industry”
  - Acknowledges the importance of “reproductive capacity to conserve the stock”
- Similar TACs when population abundance is high
- Added conservation benefit: lower exploitation when population is in decline
  - Crab less valuable: higher proportions of oldshell crab
- Proactive approach: female trends predictor of male population declines

Historical TACs (east + west)



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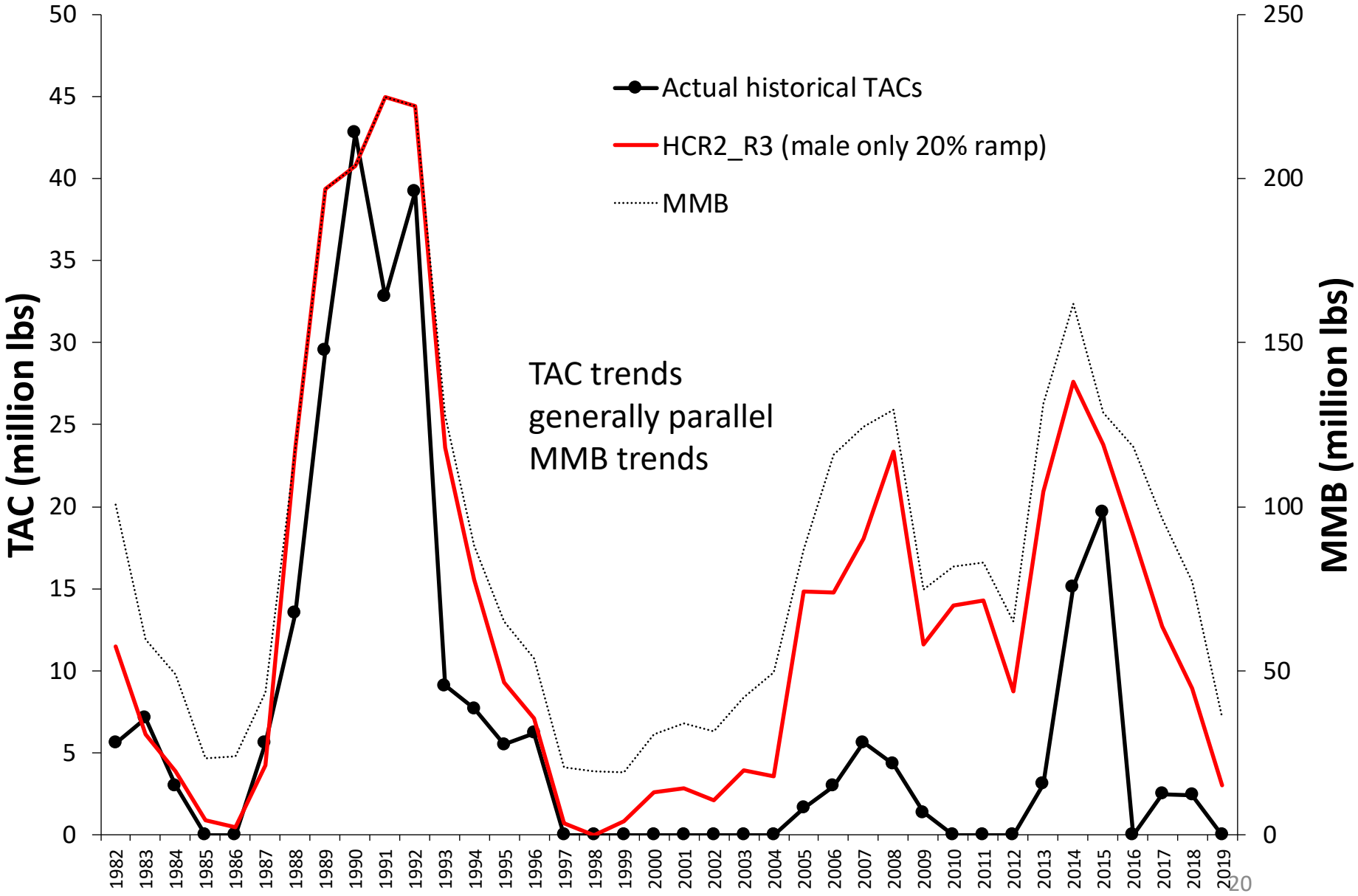
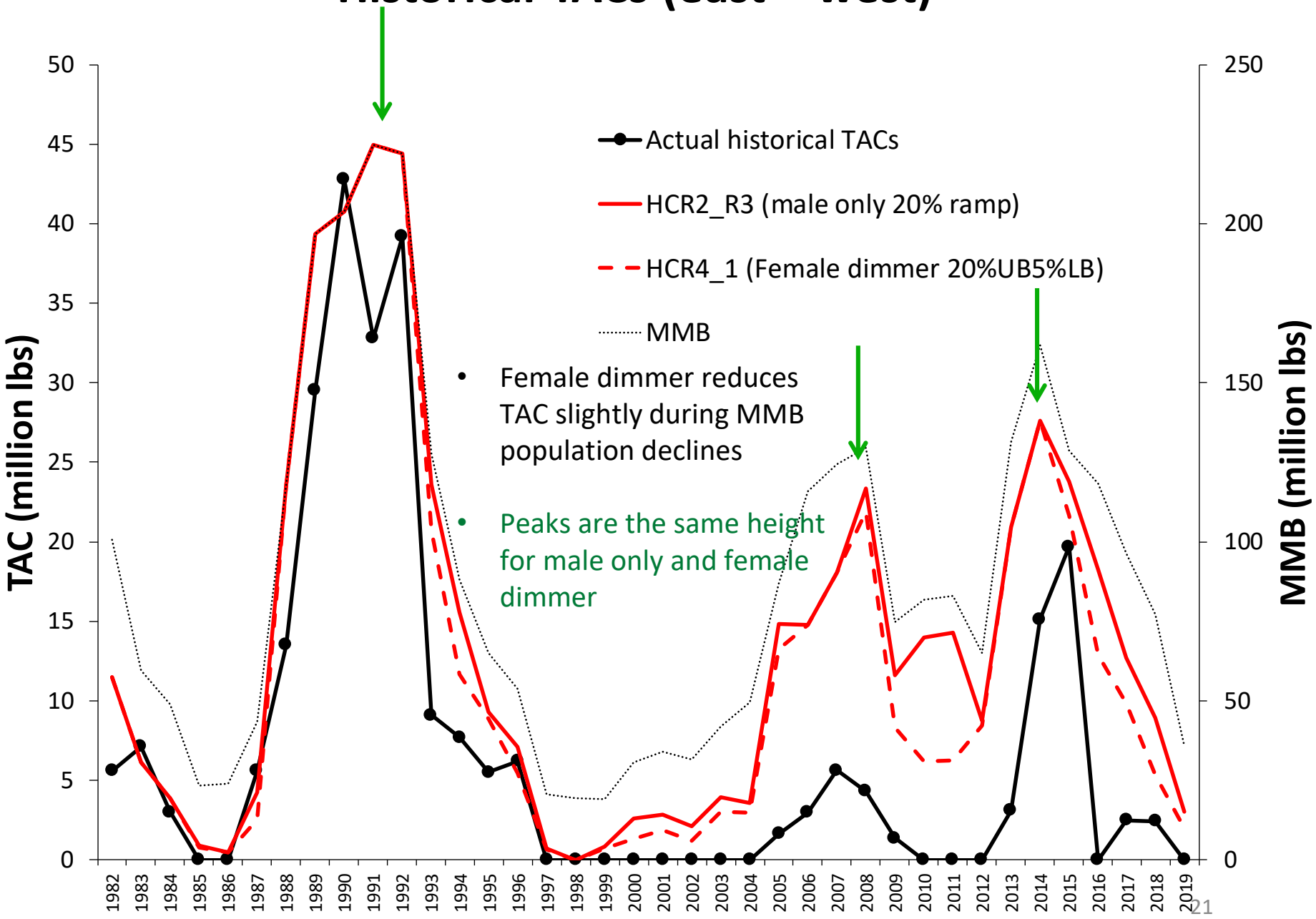
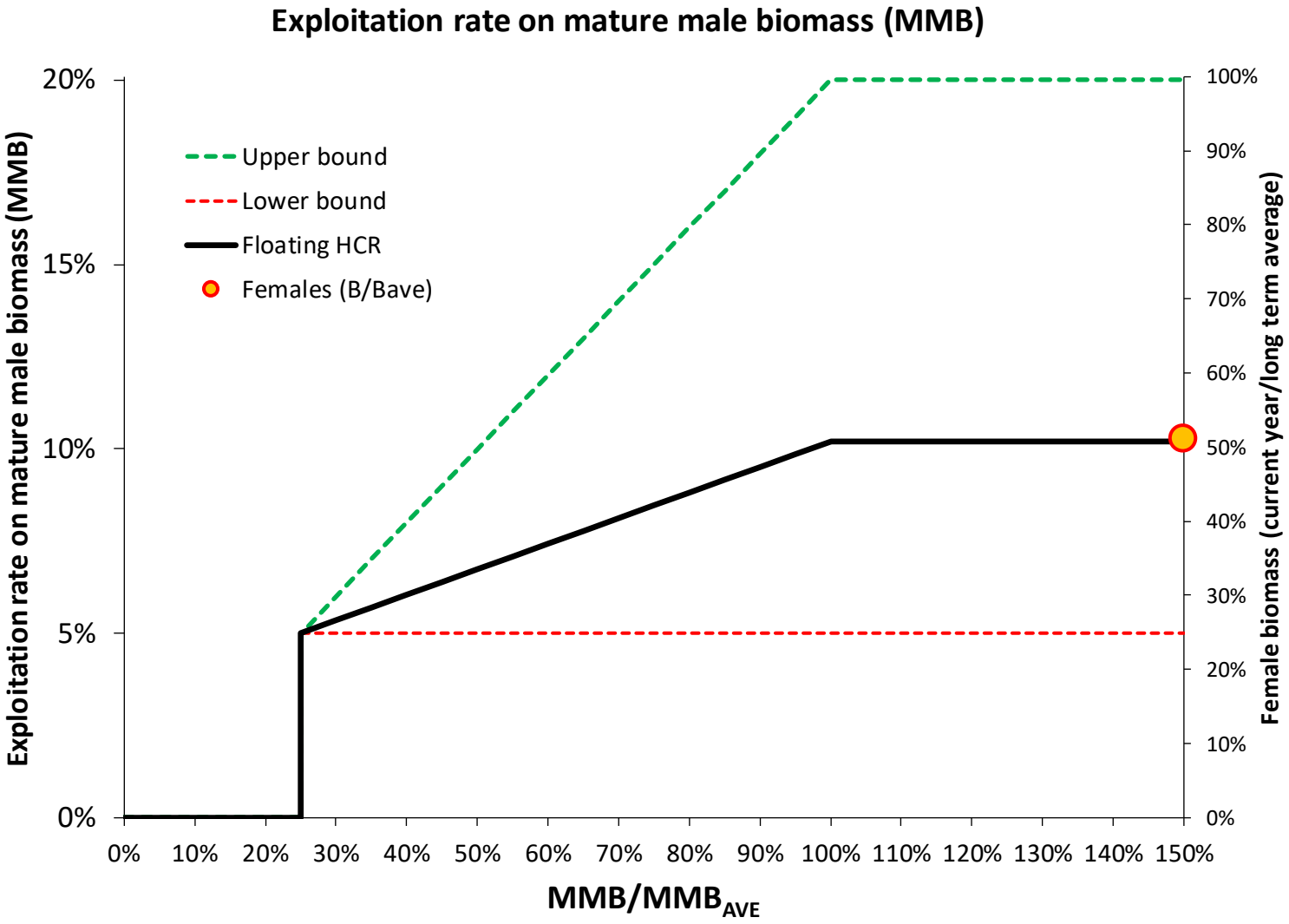


Historical TACs (east + west)





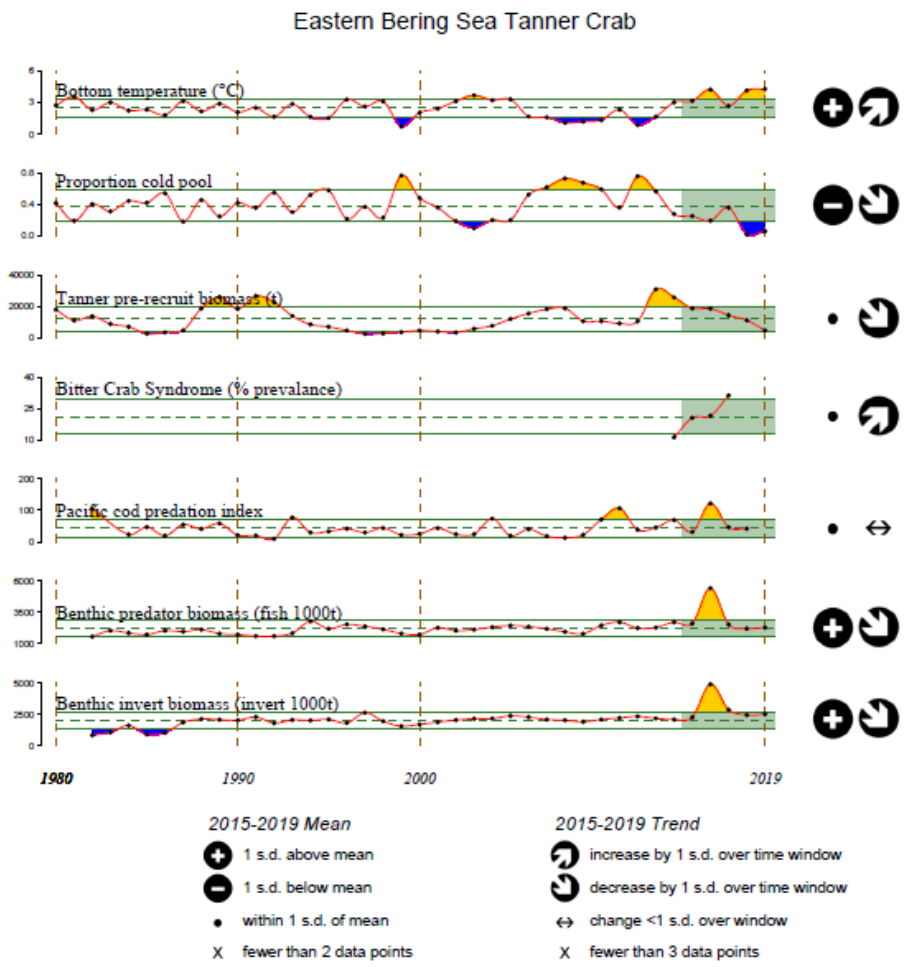
Female dimmer sub-options

Policy	Description	Fixed vs ramp	Ramp lower	Ramp upper	Max TAC
HCR4_1	Female dimmer 20%	Ramp	5%	20%	50% ELM
HCR4_2	Female dimmer 20%	Ramp	10%	20%	50% ELM
HCR4_3	Female dimmer 22.5%	Ramp	10%	22.5%	50% ELM
HCR4_4	Female dimmer 22.5%	Ramp	10%	22.5%	30% ELM

Sources of uncertainty

1. Reproductive dynamics: no S-R relationship
   - Influence of spawner population size on simulated population dynamics not fully captured in MSE
   - Effect of female control rule nebulous based on MSE results
2. Population assessment challenges
   - Model vs raw area-swept: what's the true population size?
   - Survey *selectivity* and *availability*
3. Environmental change
   - Environmental forcing not part of MSE
   - Bering Sea experienced unprecedented environmental conditions in recent years: warm temps, lack of sea ice
     - Likely suboptimal for cold-adapted species such as Tanner

Environmental Uncertainty:
NOAA Tanner crab report card



2019 bottom temps warmest in 40-year timeseries

2018 + 2019 cold pool extent lowest in 40-year timeseries

Pre-recruit (103-124 mm) continued decline, 2019 lowest since 2002

Bitter crab syndrome prevalence increasing

- **Sea ice at record lows in 2018**
- **Predicted future conditions:** continued warming temperatures and reductions in sea ice cover[1]

[1] Hermann et al., 2016. Projected future biophysical states of the Bering Sea. Deep Sea Re. II. 134:30-47

Probability total fishery mortality exceeds ABC

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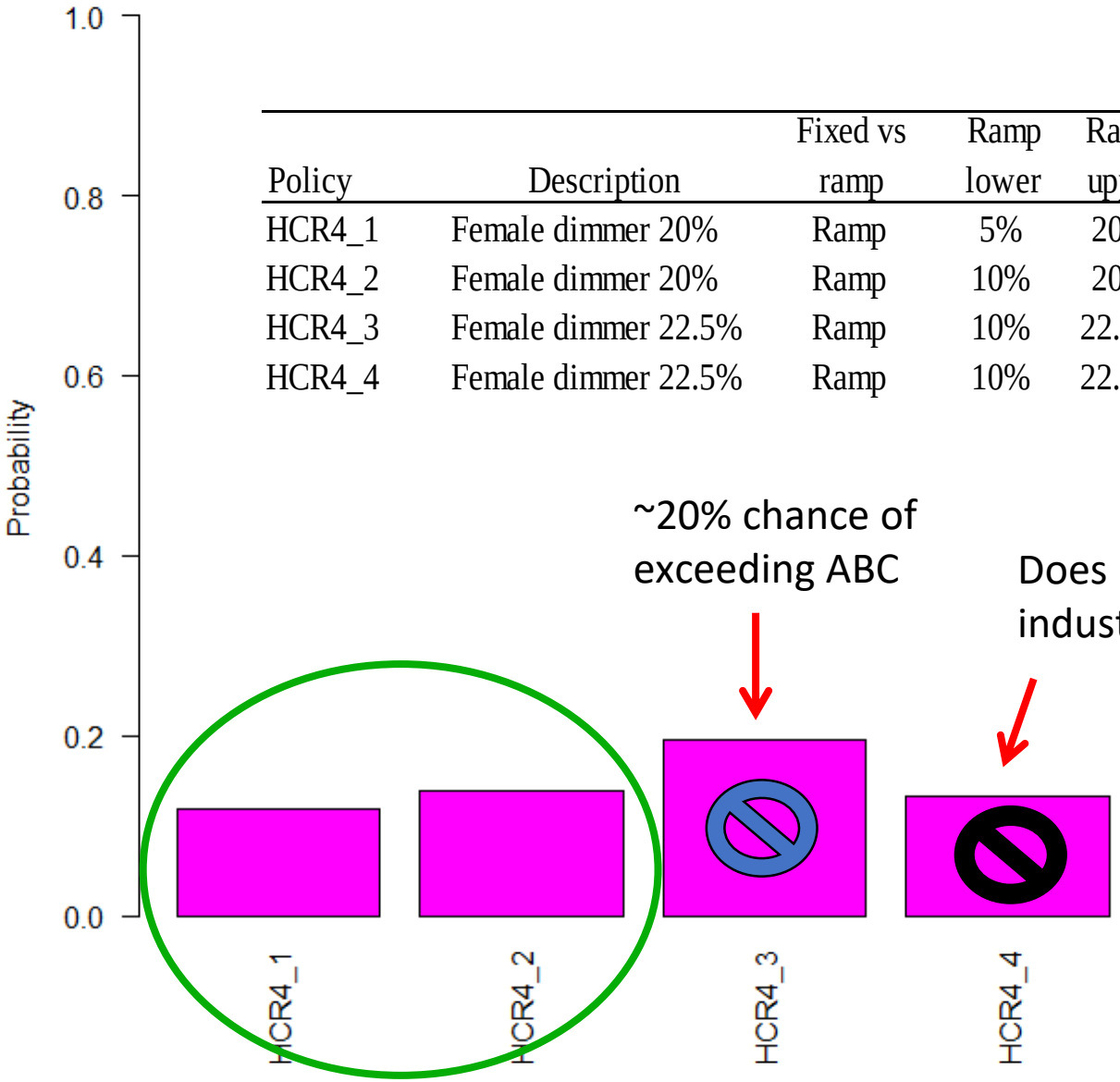
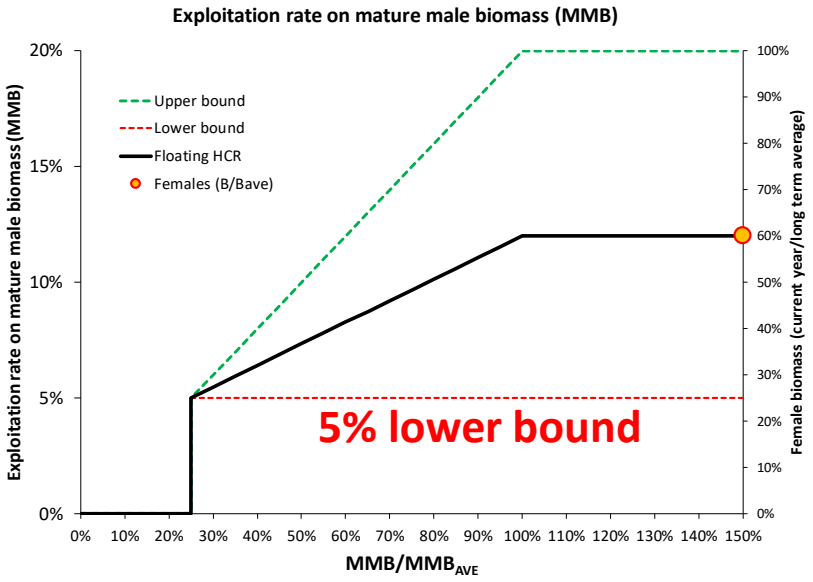


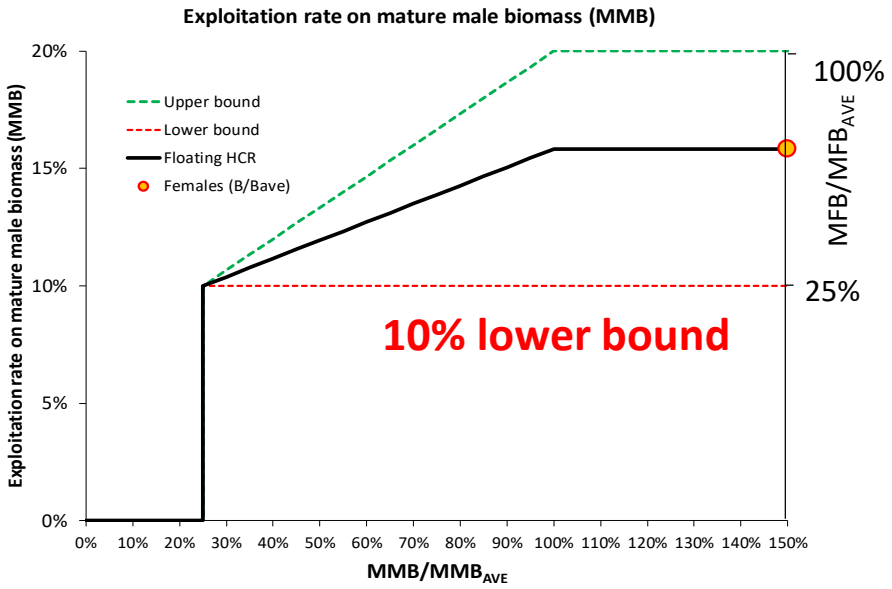
~20% chance of exceeding ABC

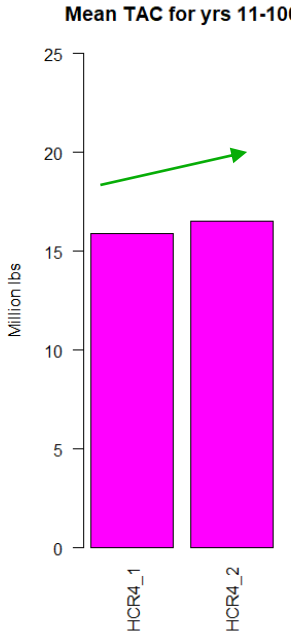
Does not align with industry preferences

HCR4_1



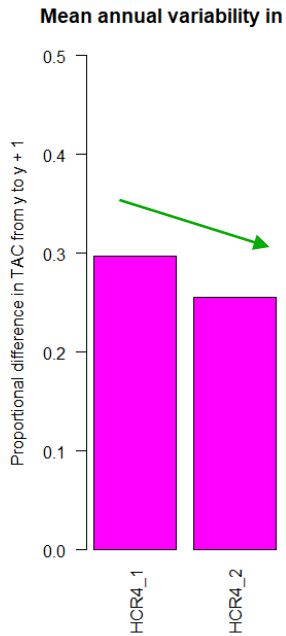
HCR4_2





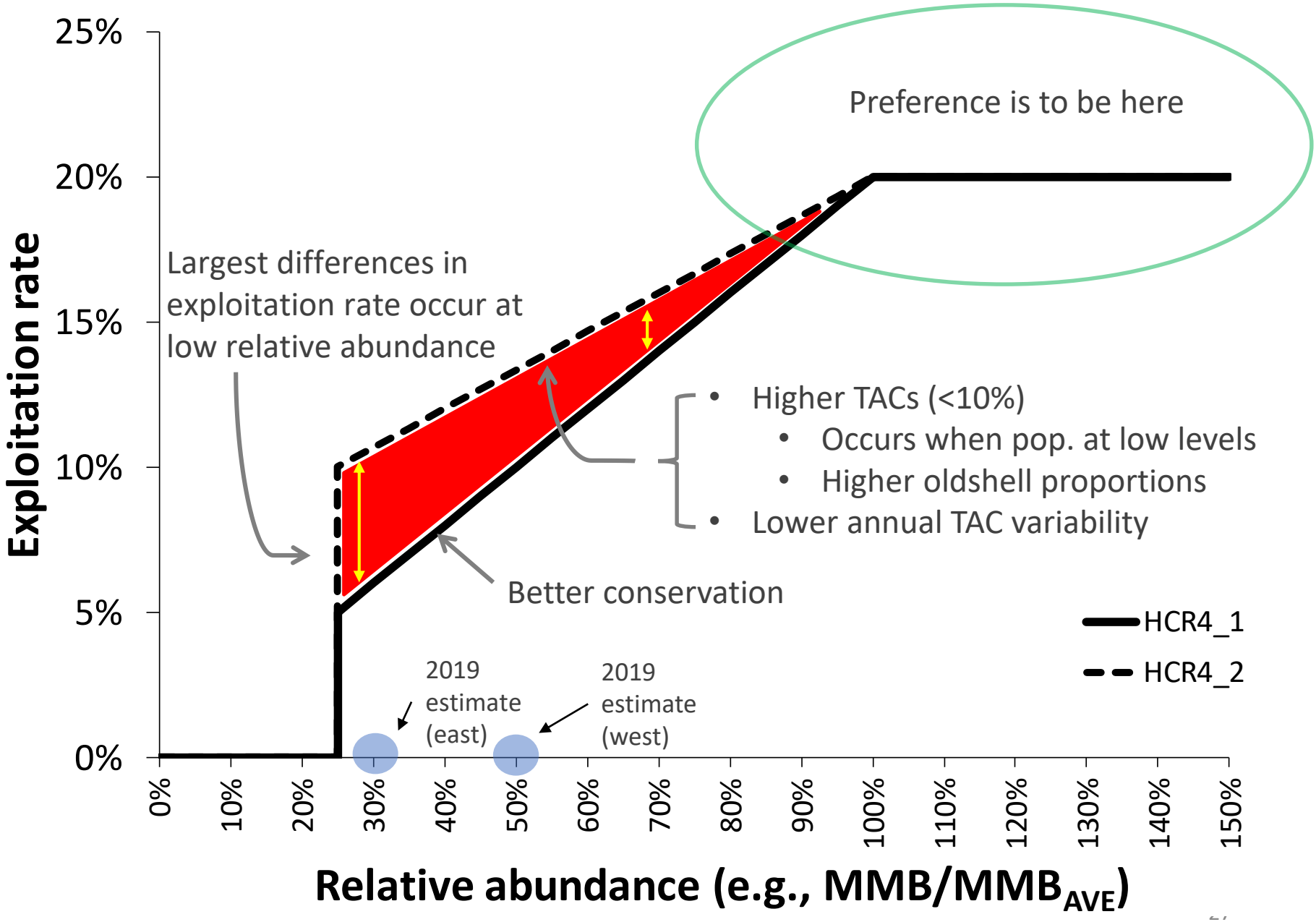
10% lower bound gets slightly higher TAC

- 16.5 vs 15.9 mill lb in MSE



10% lower bound gets lower annual variability in TAC

- 26% vs 30% in MSE


Preference is to be here
Largest differences in exploitation rate occur at low relative abundance
Higher TACs (<10%)
Occurs when pop. at low levels
Higher oldshell proportions
Lower annual TAC variability
Better conservation
HCR4_1
HCR4_2
2019 estimate (east)
2019 estimate (west)
Exploitation rate
25%
20%
15%
10%
5%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
110%
120%
130%
140%
150%
Relative abundance (e.g., MMB/MMB$_{AVE}$)

Summary: Proposal 261

Female dimmers HCR4_1 + HCR4_2

- Address 2017 Tanner workshop goals
- Precautionary and proactive approach to management
- 5% lower bound (HCR4_1) provides added level of conservation without significant economic downside
- Both HCR4_1 + HCR4_2 liberal compared to actual historical TACS
  - No fishery closures, higher TACs relative to actual historical
- Industry preference for higher exploitation (10%-22.5%)

1999-2019				Combined East + West			East	West
HCR	Ramp_UB	Ramp_LB	Max TAC	Average	Diff_act	Closures	Average	Average
Actual			NA	**2.8**		**11**	1.5	1.3
HCR4_1	20%	5%	50% ELM	9.9	7.5	0	4.3	5.6
HCR4_2	20%	10%	50% ELM	10.8	8.4	0	4.9	5.9
HCR4_3	22.5%	10%	50% ELM	11.9	9.6	0	5.5	6.4
HCR4_4	22.5%	10%	30% ELM	8.3	5.8	0	4.2	4.1

Thank you